THE EFFECTIVENESS OF ESP (ELECTRONIC STABILITY PROGRAMME) IN REDUCING REAL LIFE ACCIDENTS

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ABSTRACT

ESP (Electronic Stability Programme) has recently been introduced on the market to reduce the number and severity of loss-of-control accidents. It has been expected that this reduction would mainly be addressed to accidents on roads with low friction. It is, however, complicated to evaluate the effectiveness with more conventional methods.

In this study, data from accidents occurring in Sweden during 2000 to 2002 were used to evaluate the effectiveness of ESP. To control for exposure, induced exposure methods were used, where ESP-sensitive to ESP-insensitive accidents and road conditions were matched in relation to cars equipped with and without ESP. Cars of similar or in some cases identical make and model were used to isolate the role of ESP.

The study shows that there are positive effects of ESP in circumstances where the road has low friction. The overall effectiveness was 22.1 +/- 21 %, while for accidents on wet roads, the effectiveness was 31.5 +/- 23.4 %. On roads covered with ice and snow, the corresponding effectiveness was 38.2 +/- 26.1 %. ESP was found to be effective for three different types of cars, small front wheel drive, and large front wheel and large rear wheel drive cars.

BACKGROUND

The Electronic Stability Programme, ESP, is an on-board car safety system, which enables the stability of a car to be maintained during critical manoeuvring and to correct potential understeering or oversteering (1). In a general sense the equipment should eliminate loss of control. Since 1998, when the first mass-produced car with ESP standard equipment was launched, the market for cars with ESP has grown quickly. On some cars, however, ESP is an option, and there are still a number of car models where ESP is not available.

ESP operates normally with both brakes and engine management. If the car loses control, defined as when one wheel or more is moving faster or more slowly than calculated from the steering input and turning angle, braking is applied to one or more wheels, and the engine power might be reduced.

It has been expected, that the ESP will have a significant effect on loss of control type accidents. This effect is expected to have an influence both on the number and the severity of impacts (1), and might also change the orientation of the vehicle prior to impact (2). A projection of the effects based on in-depth data suggests that in 67% of the fatal and 42% of injury only accidents where the driver lost control, ESP would have a probable or definite influence (1). For all injury accidents, the estimated proportion of accidents addressed is 18%, for fatal accidents 34%.

While ABS (anti-locking brakes) also was subjected to high expectations prior to being available, several studies have shown, that the effects are minor, or close to none (3,4). While the accident type distribution has been found to be different for cars equipped with ABS compared to cars without, the net effect is probably less than 5% reduction of accidents with injuries (3,4).

The aim of the study was to:

- Present a method and apply it to estimate the influence of ESP on accidents in Sweden
- Estimate a possible reduction of real life accidents with injuries.

METHOD

In this study, induced exposure is used to estimate the exposure to accidents for cars equipped and not equipped with ESP. This is an accepted method to use in situations when it is not possible to calculate the true exposure (3). The method is based on the identification of at least one type of event that is not expected to be affected by ESP. For that specific case, the accident number relation between ESP and non ESP fitted vehicles would be considered as the true exposure relation. Any deviation from the established basic distribution for accidents not affected by ESP, is considered to be a result of the equipment of ESP. The method is also considered to be based on the fact that there are no other differences between cars equipped and not equipped with the system under study (ESP), or any other user related factor that would alter the expected equal distribution of events and accidents. Both these prior factors are normally complicated to fulfil and control. In the present study, not only type of accident but also the surface condition was used to estimate possible effects. In the purest form, the effectiveness is

calculated by

$$E = (A_{ESP\,/}\,N_{ESP)}\,/\,(A_{nonESP/}\,N_{nonESP)}$$
(Eq. 1)

Where E is the effectiveness of ESP on accidents sensitive to ESP. A is the number of accidents sensitive to ESP, and N is the number of accidents considered not sensitive to ESP.

The standard deviation of the effectiveness was calculated on the basis of a simplified odds ratio variance (3). While this method gives symmetric confidence limits, the effectiveness is not overestimated. The formula is given below

$$Sd = E\ (SQR\ (SUM\ 1/n))$$
(Eq. 2)

Where n is the individual number of crashes of each type. The confidence limits are 95%.

A critical part of the method is to choose and identify cars that are identical in every other factor than the presence or absence of ESP. This is in reality very complicated, as ESP is firstly not a random equipment, but has sometimes to be ordered separately or was introduced in a sequence where none of the vehicles of a particular model had ESP, and after a certain date, all had. The third possibility is when a vehicle has ESP as standard equipment on some of the versions of a model range, often linked to other differences. There is no record of ESP equipment kept in the register of vehicles in Sweden. In this study, the focus has been on finding two sets of vehicles, with and without ESP, where ESP was introduced as standard equipment at a certain point in time. The benefits are that the selective bias in picking ESP as option, or choose a car with higher specifications, is avoided. On the other hand, a car with and without ESP has not been subjected to the same conditions otherwise. If the same time is picked for the analysis, the cars without ESP is on average older than cars with ESP, or if the age of the cars is identical, the time at which they were exposed is not the same. It is, however, not impossible to control for these confounders, as the history for the cars without ESP could be analysed as to what happens when the car gets older.

In this study, products mainly from Mercedes-Benz, BMW, Audi and VW were included in the analysis as case cars. The majority of the cars picked would be classified as more upmarket models, but there are some that would be considered as models attracting a wider part of the market, such as MB A-Class, Audi A3/A4 and VW Passat.
The other critical part of the method is to pick accident types and/or road surface conditions that are considered to be insensitive to the effect of ESP. It is important that this part is done a priori to the analysis. The approach used in this study was to use the results of a European multi centre assessments of where ESP would have an impact (1). In the European multi centre study, expert teams assessed on a number of in-depth studies in a scaling system how much ESP would have contributed. It was found, that accidents in intersections would not have been benefited much by ESP, while other types of accidents would have been affected to a varying degree. Also, lower friction, in this case rain, is a risk factor.

In the present study, rear end impacts on dry surface were considered insensitive, and both wet roads as well as roads with snow and ice were treated separately. The reason for picking only rear end impacts, was that it is one of a few accident types that alone on just dry road conditions would constitute enough cases to be used. Logically, it is also an accident type that would not involve much of vehicle handling factors. This is an even more limited accident type than proposed by the study mentioned above, which has the advange that effects of ESP could be picked up over a more varied set of accident types. A broader set of accident types would have limited the possibility to estimate the overall effect of ESP. The disadvantage by not disaggregating the effects on idndividual accident types is abvious, but the data set was not large enough to allow such a detailed analysis.

MATERIAL

The data set was constituted by police reported accidents with at least one injured person in Sweden. All crashes from the years 2000 to 2002 was used to select crashes with vehicles from model year 1998 to 2003. All crashes recorded by the police contains at least on injury. From vehicle model codes the car models with electronic stability program (ESP) were specified. Matched controls were identified also by the model codes. The controls were selected to be as close as possible to the case vehicles. In many cases the same model or model platform was used as control. Table 1 shows the vehicle models used in this study. In all 442 crashes with ESP equipped cars were found. The control group contained 1967 crashes. For every crash the road condition, dry, wet or snowy/icy was used together with the collision type. For car to car crashes it was known if the vehicle under study was the striking or struck part. To indicate the speed limitzone the actual speed limit at crash site was

used to calculate average speed limit

Table 1.
Car models used for the calculations

Small front wheel drive models			
Case car models	Control car models	Case cars	Control cars
AUDI A2	AUDI A3	10	1
AUDI A3	VOLKSWAGEN GOLF 1998-	98	281
MERCEDES-BENZ A-CLASS		66	
	Sum	**174**	**281**
	Average speed limit (km/h)	*66*	*69*
Large front wheel drive models			
Case car models	Control car models	Case cars	Control cars
AUDI A4 2001-	AUDI A4 1994-2000	29	162
AUDI A6	AUDI A6	43	83
CITROËN C5	CITROEN C5	7	8
PEUGEOT 607		6	503
SAAB 9-5	SAAB 9-5	10	
VOLKSWAGEN PASSAT 4	VOLKSWAGEN PASSAT 4	45	430
	Sum	**140**	**1186**
	Average speed limit (km/h)	*69*	*70*
Large rear wheel drive models			
Case car models	Control car models	Case cars	Control cars
BMW 3-SERIE 98-	BMW 3-SERIE 98-	36	99
BMW 5-SERIE 96-	BMW 5-SERIE 96-	34	67
MERCEDES-BENZ C-CLASS 203 2001-	MERCEDES-BENZ C-CLASS 202 1994-2001	25	38
MERCEDES-BENZ E-CLASS W210 1996-2001	MERCEDES-BENZ E-CLASS W210 1996-2001	9	295
MERCEDES-BENZ E-CLASS W211 2002-		3	
MERCEDES-BENZ S-CLASS 99-		3	
	Sum	**110**	**499**
	Average speed limit (km/h)	*63*	*65*
Others	**Sum**	18	
	Total Sum	**442**	**1967**

While police reported accident data is known to suffer from a number of quality problems, none of them is likely to influence the findings of this study to any large degree.

RESULTS

The results are based on the assumption that rear-end accidents on dry roads are not, or only slightly, affected by the presence or absence of ESP. Both ESP vehicles and the selected controls are all equipped with ABS, so there should not be any influence of such a factor. A factor that would harm the analysis is if there was a risk compensation for cars with ESP. A higher average speed would result in an overrepresentation as a bullit car in rear end collisions. In such a case, the calculated effectiveness would be overestimated. One way of controlling this factor in rear end accidents is if ESP cars were more involved as bullit cars in relation to be target car. The bullit to target distribution of cars with and without ESP is almost identical (44% and 47% respectively as target car).

The results presented were based on a selected sample of control cars. There was also a control calculation performed using all post 1998 car model vehicles and their accident distribution. This control group and the used matched control group show an almost identical distribution of rear end crashes to other crashes, as well as the distribution of accidents on the three road surface types used in this study. The selected and used control group therefore does not seem to differ from the rest of the car population, and the case group does not differ from the control, group in the accident type that is used as the exposure basis (rear end collisions on dry road surface).

In table 2, the calculated effectiveness of ESP for different road conditions, is given. It can be seen, that while the effectiveness on all road conditions, and for all accidents except rear end impacts, the effectiveness is 22.1%. The 95% confidence limit is just over the zero effect limit, so the effectiveness estimate ranges between 1.1 % and 43.1%.

For accidents on low friction surface, the effectiveness estimates are clearer. On wet roads, the effect is at least 7.8% with the 95% confidence limits. These accidents account for 30% of the accident population. On roads covered with ice or snow, the effectiveness is even higher, at least 12.1% (lower bound of the 95% confidence limit). These accidents account for 10% of all accidents during the study period among controls.

For accidents on dry roads, there was no significant effect.

Table 2.
The effectiveness of ESP on accidents with personal injuries. 95% confidence limits. All estimates are reductions in relation to rear end impacts on dry road surface

All accidents excl rear end	22.1 +/- 21.0%
Accidents on dry roads	9.3 +/- 28.3%
Accidents on wet roads	31.8 +/- 23.4%
Accidents on snow/ice roads	38.2 +/- 26.1 %

In table 3, the effectiveness estimates were broken down into three car types, small and large front wheel drive (small fwd and large fwd) as well as large rear wheel drive cars (large rwd). The road surface wet and covered with snow and ice were added to constitute a group of "low friction surface".

Table 3.
The effectiveness of ESP on accidents with personal injuries, by vehicle type. Point estimates. Significance levels 5%, double sided. All estimates are reductions in relation to rear end impacts on dry road surface

Type of car	All accidents	Accidents on low friction
Small fwd	28.0% ns	24.5% ns
Large fwd	21.4% ns	58.9% s
Large rwd	44.8% s	46.0% s

It can be seen in table 3, that there was a significant reduction of low friction accidents for the both large car types. With a larger data set for the small cars, the effectiveness would still be substantial if the point estimate would be at the same level as shown here.

DISCUSSION

This study was a first attempt to evaluate a new technology. It is important to stress, that this type of evaluation, should be a normal exercise when technology aimed at reducing health losses in the society, is implemented. It is also important to stress, that while such analyses are complicated to conduct, they should be done on a broader basis than just in one country. In this case, the study was done in a small country, with limited numbers of accidents subject to the study, which limits the possibility to draw conclusions. It would be of major interest to the global society if studies of new technologies could be jointly conducted in many countries at the same time.

It is important to stress, that the weather conditions in Sweden are different from many other countries, making it impossible to generalize the results from this specific study to all parts of the world. It would therefore not be surprising to find other estimates of the effectiveness if accidents from other countries are analysed. On the other hand, the results of the present study show, that positive results shoudl be expected in countries with a different climate as well.

ESP (Electronic Stability Programme), is a technology that helps the driver to maintain control of the vehicle in critical situations. Such technique has been implemented and evaluated earlier, in the form of Anti Locking Brakes (ABS) with quite disappointing results. No or only minor effects has been found (2, 3), even if there has not been any behavioural adaptations in driving more aggressive with cars equipped with ABS.

ESP is functionally different from ABS, but there has not been any evaluation of the system in real life critical situations published. While this study can bring some knowledge as to how effective ESP is, it is still very important that more studies are conducted.

The method used for this study has been used in many other types of evaluations (3,4). It is a method that is dependent on a number of assumptions and critical factors. It should be understood, that new vehicle technology is not brought into the market in a way that would guarantee a scientific evaluation. First of all, the technology is not randomly equipped to vehicles, and there is probably a selective recruitment to such technology. Secondly, ESP seems to be brought to the market on more up-market car models, and vehicles in high-performance versions. Attempts have been made in this study to overcome this problem, but there are still some doubts about how the technology is picked up by consumers. The novelty of the technology might even lead to , that drivers of cars with such technology will provoke the system to act, or that there are some behavioural modifications. These phenomena are very hard to control for, but might modify the long-term effectiveness of ESP or similar technologies.

In this study, only vehicles where ESP became standard equipment at a certain moment of time were included. In most cases, where ESP was an option, the car model was excluded. The selective recruitment bias should therefore be minimised. On the other hand, this method meant, that cars otherwise identical with and without ESP never existed in parallel time with identical age of the car. Other studies should try to pick up this factor. The fact that ESP has been introduced on fairly up market car models is a restriction on the possibility to generalise the results. Some controls are car models different from ESP cars, which were sold at the same time as ESP cars. This should reduce the type of bias mentioned above.

The results are extraordinary, in that the effectiveness of ESP is large and consistent, and not just on an isolated accident type or event It is therefore essential, that the method and the possible bias, are challenged. There are a few possible explanations to the results, given that ESP was not effective in reducing the accidents. Firstly, if rear-end impacts was an accident type, where ESP drivers showed their aggressiveness and risk compensation more, than in all other accident types, the results could show the same profile as in this study. The fact that both ESP cars and non-ESP cars show the same profile in being target and bullet vehicles in rear is an indication of that this assumption does not show in reality. Secondly, the same results could be present if ESP cars were not exposed to driving on low friction surface. Such factor is very complicated to analyse with induced exposure. It is, given the way the data was assembled, not a plausible explanation. Still, the study should be repeated also in Sweden, also to study the long term effects of ESP. In the meantime, the likely explanation to the results is, that ESP in fact is effective.

The method used in the present study, does not allow an analysis on the actual function of the system, and in what sequence of driving it has its potential. Wheather ESP works as an intelligent system to warn the driver about low friction, or if it has a direct function in the driver-vehicle loop in critical manouvers, either in controlling stability and/or reduce speed, was not possible to study. It was not possible to study to what extent the effectiveness varied over accident types or events. Further studies should try to analyse this in-depth. It should also be analysed, if the severity of impacts is reduced by ESP.

A recent development of ESP that would most probably increase the effectiveness is the link between the ESP being active and the passive safety system of the car being alerted and start to act. In Mercedes-Benz S-Class update 2002, both the ESP and the brake assist system will trigger a reversible seat belt pretensioner, to bring the occupant in a favourable position before a possible crash. Also other functions of the vehicle are also triggered. In this sense, the ESP is used as a device for increasing the crash protection of the car.

The effectiveness of ESP is promising enough, to stimulate automotive industry and consumers to implement ESP in new cars as quickly as possible. Therefore, consumers should be advised to choose cars with ESP, especially in countries with wet and icy road conditions. While the effectiveness on dry roads was not significant, accidents on both wet as well as roads covered with snow or ice were significantly reduced.

CONCLUSIONS

- ESP was found to reduce accidents with personal injuries.

- The effectiveness on all accidents, except rear-end impacts on dry road surface, was 1.1% to 43.1%, with best estimate 22.1%

- The effectiveness on roads with lower friction was substantially higher, 7.8-55.2% and 12.1-64.3% (best estimates 31.8 and 38.2%), for wet roads and roads covered with ice or snow, respectively.

- The results broken down to vehicle types were consistent with the above results, in some cases though not statistically significant.

RECOMMENDATIONS

- Consumers should be recommended to buy cars with ESP, especially in countries with wet or icy road conditions.

- Further studies should be made, to validate the results of the present study, and increase the understanding of the mechanism of the improvement.

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